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Generally Speaking

Wednesday's Child?

A new York diamond salesman has recently had half a million dollars worth of diamonds snatched from him by a bandit, who used tear gas to disable his victim. We feel that, with or without gas, an extraction like this is certainly a good reason for tears.

More Explorers

We have just been reading a fascinating account* of diamond prospecting in the wildest parts of Venezuela. The author, an Italian, made a number of journeys into the interior of the country, and he and his companions found some diamonds, and a great many other things as well.

Even if the expeditions were not particularly successful as regards the discovery of diamonds, they provided material for a first-rate real life adventure story, and some magnificent photographs of the incredibly difficult country in the interior of Venezuela.

How up-to-date are you?

We get a great many trade literature of all sorts sent to us—sometimes we are hard put to it to see what our connexion with the subject dealt with is—and on the whole they are admirable productions. They are often profusely illustrated, beautifully printed, and well and clearly written Some of them, it is true, are none of these things, but those are in the minority. But, good, bad, or indifferent, they nearly all have one fault in common, and it is a serious fault: very few of them have any indication of their date of issue. Now this is very often a most important piece of information and it should never be left out. How else are we—or anyone else—to know if what we are reading is really up-to-date, really the latest practice of the firm concerned?

* 'Diamanti' (Gran Sabana-Caroni) by Alfonso Vinci : published by 'Leonardo da Vinci' Editrice, Bari, Italy, 1957. 2.500 Lire.

*New Opinions on Grinding and Polishing especially of Metallographic Specimens**

Z. Ministr**

(CONCLUSION)

5. *Forming flat specimens*

An over-all curvature is formed when the specimen is manually held, especially when the specimens are small. There are various opinions regarding the size of specimens. It is true that with a large specimen, having an area of several square centimetres, it is easy to achieve a more perfect evenness than with small specimens, but on the other hand it must be admitted that smaller specimens are ground more quickly. In addition, consumption of expensive abrasive in grinding with diamonds is directly dependent on the dimensions of the ground area. We must also be aware that a few tenths of a square millimetre are sufficient for structural examination, since the diameter of the visible area is only several tenths of a millimetre.

For these reasons, small specimens have recently been used, prepared in such a manner as to increase the bearing area and to achieve an even surface more easily.

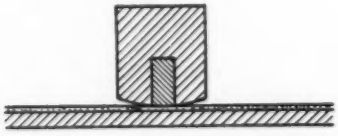

Fig 5. A mounted specimen curved in grinding by hand, due to differences in the hardness of the mounting plastic and the specimen.

Since a softer mounting plastic, for example Dantacryl[d], is ground off much faster than the specimen itself, a curvature such as in Fig 5 is formed when the mounted specimen is held manually. This imperfection is easily eliminated by putting the mounted specimens into a holding device, for example as described in *Hutnicke Listy*[3]. The purpose of the mounting plastic is then no longer to increase the bearing area but to form a conically shaped mount, which is easily fixed in the holding device. The contact area of the mounting plastic and the abrasive medium is a minimum, because in grinding with diamond the mounting plastic sticks to the paper and forms a tough greasy coat, which can indeed be removed by a suitable solvent, but with appreciable loss of the very expensive abrasive.

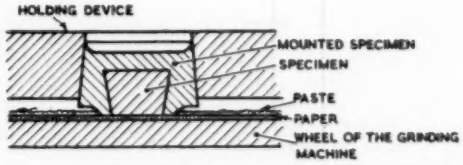

Fig 6. Ideal shape of the mounted specimen clamped in a holding device.

An ideal shape of the mount clamped in the holding device is given in Fig 6. The conical shape of the part projecting from the holding device also facilitates penetration of the grinding paste between the specimen and the paper support, and prevents accumulation of the paste along the edge of the mounted specimen.

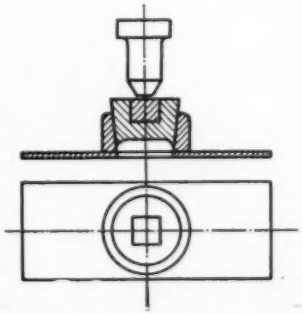

Fig 7. Device for the adjustment of conical shaped mounted specimens under the objective.

Besides the above mentioned advantages, the conical shape of the mount also provides a further advantage; it can easily be placed under the objective for microscopic examination, since the ground area is perpendicular to the axis of the holding device (Fig 7).

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* An abridgement of a lecture delivered in the metallographic exposition in Prague, organized by the Czech Scientific Technical Society for Metallurgy in the Czechoslovak Academy of Science, May 1956; *Hutnik* 1956 Vol 6 (9) pp 257-262. Translated by B. Sudek.

** Powder Metallurgy Research Institute, Vestec, near Prague.

d Dentacryl is a high-molecular plastic produced by the Dental State enterprise in Prague.

6. *Suitable polishing vehicles*

With specimens mechanically polished on fabric, a rounding of the edges of the specimen or of its cavities inevitably occurs, even when the specimen is mounted in a fairly hard material. Rounding also occurs on the boundaries of two components, differing in hardness and structure, or on the boundaries of two different materials, for example with metallic coats, etc.

This is caused by the elasticity of the fabric fibres, on which the polishing suspension of some oxide, usually with spherical or plate-shaped grains, is dispersed. The polishing grains are elastically supported by the curled pile of the fabric, and the extent of the resilience is dependent on the hardness of the polished material. Furthermore, different structural constituents have a differing resistance to wear; this cannot be altered and in heterogeneous material inevitably causes the formation of a micro-relief, or of small steps with coatings.

On pile cloth with curled woollen fibres, the polishing suspension is retained, but in addition the above mentioned curvatures are easily formed. Felt fabrics, (*eg* billiard cloth) can be used only for polishing homogeneous materials without cavities, where the rounding of the outside borders of the specimen is not so important.

A more perfect plane is achieved by pile fabrics (velvet), where it is important that the fibre should be as short and as dense as possible, its length being uniform and the fundamental binding strong, without changing its properties when wet. Special fabrics of this type have not been produced in Czechoslovakia until now, but there is very urgent need for them there. For fine grinding with diamond powder, a fine synthetic chamois cloth (Selvyt) is suitable according to some references[14,15]. The short synthetic fibres are glued to the linen-like base by an elastic paste resistant to water. During gluing, the fibres are erected by the action of an electrostatic field.

A disadvantage of pile fabrics is that, for saturation with fine diamond powder of grain size of 1 to 3 microns, an appreciable amount of powder is required. Further, a small curvature of the borders or a wavy shape in the boundaries of structural constituents occurs, especially in a circular movement of the specimen on the wheel. The polishing must be performed quickly and stopped at the moment the parallel scratches disappear, although non-parallel scratches still occur here and there on the surface of the polished specimen.

From my own experiences the most suitable support for very fine grinding (polishing) with diamonds is the reverse side of ordinary photographic paper. Really outstanding results can be achieved not only in the preparation of heterogeneous sintered alloys but with all materials.

Paper has a relatively slightly graduated surface, so specimens maintain an even surface almost up to the edge. Since a water suspension cannot be spread on paper, various oils or pastes are used. A correspondingly dense paste soluble in water, the preparation of which, due to Samuels, I have tested[16] has, in my opinion, three essential advantages over oil suspensions:

1. In spreading the paste on the cover of the wheel, a uniform dispersion of diamond grains across the entire area of the wheel can be easily achieved. On the other hand, a drop of an oil suspension leaves the powder just where it has dropped, and pure oil shows a capillary action with paper without carrying the powder with it.

2. When diamond grains are dispersed in a relatively thick medium, they are better predisposed to grind: being held more strongly in a certain position the kinetic effect of the moving grain is more effective. When, on the contrary, the grains are dispersed in a relatively thin oil, the plate-shaped diamond grains lie flat through the influence of adhesion, and they polish in the usual manner by smoothing the surface of the specimen.

3. A further advantage of the paste being easily soluble in water is that metallographic specimens can be easily washed in a stream of warm water.

Conclusion

Considering the increasing demands on the quality of preparing metallographic specimens, it is necessary to call more attention especially to their grinding, as the result attainable is very dependent on it.

The aim of new methods of grinding is to diminish the thickness of the deformed layer (B-layer) to the greatest possible extent and to achieve a perfectly smooth plane in a short time through simple means. Among these—apart from wet mechanical grinding—the adoption of finer abrasives than have so far been used, and which must be harder than the material to be ground, is particularly important. Diamond powder has exceptionally good qualities for such fine grinding. Diamond dispersed in a paste on paper permits the achievement of a specimen surface practically smooth and even right up to the edges.

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OBITUARY

Dr. J. T. Williamson, M.A. B.Sc.

Within six weeks of the death of Sir Ernest Oppenheimer, another of the leading figures of the diamond world has gone. Dr. J. T. Williamson, discoverer and owner of the mine at Mwadui, that bears his name, died at the age of 51 on January 8, 1958, after a long illness.

His discovery of the mine was a triumph of scientific knowledge patiently and skilfully applied. Having decided to his own complete satisfaction that diamondiferous pipes must exist in the northern part of Tanganyika, he continued to search, overcoming all difficulties, until at last, in 1940, he was successful.

During most of the time that his mine has been in operation, it has marketed its output through the Diamond Corporation, as it does at present. Dr. Williamson retained a very close and intimate personal control of the mine and, indeed, rarely left the neighbourhood. He was a man of most humane outlook, taking a great interest in the well-being of his employees, and giving considerable sums to charity, whilst living quietly and unobtrusively himself.

His interest in the mine passes to his brother and sister (he was not married) and it is understood that no changes of the method of management are contemplated.

Mr. Joseph C. Ginder

The British diamond industry and international diamond circles lost one of their best known members with the death, at Colombo, on February 3, of Mr. Joseph C. Ginder, Managing Director and Chairman of J. & C. Ginder Ltd. of London, Antwerp, and Canada at the age of 75. He was making a business trip, one of the many he made, in a life time devoted to diamonds to all corners of the world.

He had a very wide range of knowledge of diamonds and in his earlier days he even "grub staked" diamond miners and bought diamonds in the field. The business of which he was head received and handled raw diamonds and sold them polished in a variety of cuts.

Apprenticed at 13 years of age, Mr. Ginder spent almost 60 years in the trade. He will be remembered as the founder of the Diamond Manufacturers Association in 1940, and its first Chairman, an office which he held until 1957 when ill health forced him to vacate it. He was then elected the Association's first President. For many years he was a Director of the International Diamond Manufacturers Association, and it was only in July of last year that he retired from the chairmanship of that body.

Choosing The Right Diamond For Drilling

In our October 1957 issue we published an abridgement of an article from *Engineering & Mining Journal* [1957 pp 87-91 (June)], dealing with the selection of diamonds for various drilling operations. A revised version of Table I, supplied by Patrick Adamson of the Wheel Trueing Tool Co, has now been published [*Engineering & Mining Journal* 1957 Vol 158 (12) p 106 (Dec)] and we give the new version below:

Density of ground	Geological formation	Diamond size range (per carat)	Matrix*
Very soft	a. Massive unbroken (chalk)	8 to 16	Standard
	b. Broken (fine clay)	8 to 16	Standard
Soft	a. Silt shale	8 to 16	Standard
	b. Weathered shale	8 to 16	Standard
Medium hard	a. Sandstone	16 to 30	Standard or 'L' hard
	b. Fractured sandstone, etc	8 to 16	Standard or 'L' hard
Hard	a. Hard limestone or dolomite	30 to 60	Standard or 'L' hard
	b. Cherty broken limestone	16 to 30	'H' hard
Very hard**	a. Hard igneous rock	60 to 110	Standard
	b. Fractured igneous rock	30 to 60	Hard

* Rockwell 'C' scale hardness (approximate)

Matrix	*Rockwell*	*Application*
Standard	5 to 20	For all general drilling
'L' hard	20 to 32	More abrasive resistant
'H' hard	32 to 60	Fractured or broken rock

** For hematites, jaspers and or taconites, use 60 to 110 per carat in uniform solid rock ($10 50 quality); but use lesser quality or impregnated type in fractured or broken ground.

Select the quality of diamonds to be used on a 'per-foot cost basis', determined by comparing results.

The Polishing of Glass *

E. Brueche and H. Poppa

Grinding serves to give a glass surface its desired form in the rough. In this process, hard grains are pushed and rolled over the surface with iron as the opposing surface. Thus the glass is subjected locally to pressure and tension. The glass will crack at a tensile stress of 3 to 9 kg/mm² whereas it can withstand a compressive stress ten times as great. In grinding, in contrast to the completely different physical processes of polishing, the glass is loaded above the limits of elasticity and flow.

In earlier days, Preston (1922) made a thorough study of the basic technical processes of grinding glass. With an ordinary microscope, using visible light, he observed the sequences of cracks that arose when a sliding or rolling body was moved over a flat surface, and related them to the grinding process. It can easily be shown how strains result from the elastic and plastic deformation of the glass, and how transverse cracks running into the glass vertical to their track must result. These transverse cracks occur in the region near the track; with a sliding body they are inclined in the direction of the movement, but with a rotating body they are inclined in the opposite direction.

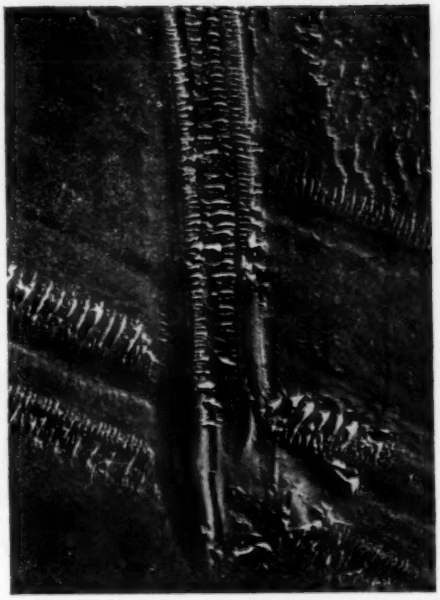

Fig 2. 'Chatter flaws' on fire-finished glass surface (7,500 × magnif).

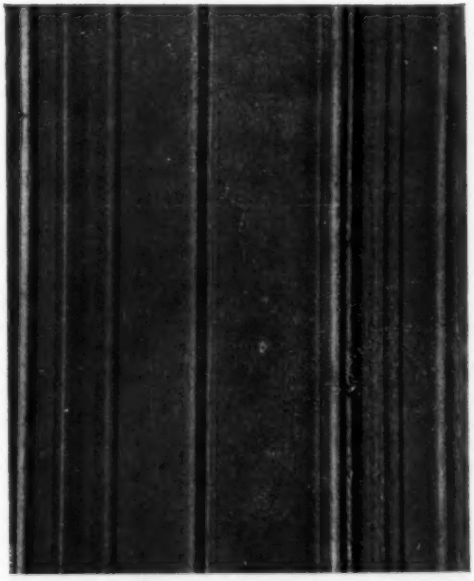

Fig 1. 'Sleeks' on fire-finished glass surface. Plastic deformation without fissuring (4,800 × magnif).

These basic processes can be seen very clearly in the electron microscope if a flat surface is exposed to suitable dynamic forces. The slight stress created by sliding grains results in purely plastic deformation (Fig 1). With higher stresses transverse cracks appear, Preston's 'chatter flaws' (Fig 2). If the stress becomes still higher, pieces break away from the surface or, in certain cases, conchoidal breaks occur due to cracking downwards from the surface.

In this way the glass surface is broken up by a multitude of cracks during the grinding process. More and more pieces break away, and finally a rough surface full of holes and notches of various depths is left (Fig 3). After the glass object has been rapidly worked to the desired geometrical shape, the next step is to reduce this surface

* Reprinted by permission of the Editor from the Journal of the Society of Glass Technology (1956 Vol 40 (197) pp 513T-519T (Dec)).

Fig 3. Ground glass surface (1,600 × magnif).

layer, full of peaks and hollows, from a thickness of perhaps 0.1 to 0.01 mm to a smaller thickness. This is done by the use of finer emery, until at last the surfaces are sufficiently finely ground. However, even these finely ground surfaces are still definitely rough, and below the surface the system of cracks may extend to a depth of several microns. The grinding process is carried out as thoroughly and carefully as possible, so that the layer affected will be quite thin. Of course, it is doubtful whether the often high standards needed for continuous operation of the polishing process can be met, since polishing is fundamentally quite a different process. The conception of polishing as a grinding process using finer materials is not accepted today.

The plasticity of glass in the micro-region

At normal temperatures glass is a liquid of very high viscosity. In the usual stress-strain diagram it does not show the transition zone between the limits of elasticity and the cracking zone that is a characteristic of metals. Moreover, the flow range is absent.

If the behaviour of glass is studied in the micro-region, however, the plasticity phenomena shown in Fig 1 will be revealed. Before the appearance of chatter flaws, the glass surface is plastically deformed by the application of small forces (but considerable pressure). Thus, for example, when a diamond point is pressed against glass, the material is plastically displaced to the sides, and a diamond powder or a particle cutting diamond, used at a low pressure, will leave behind a scratch mark which has its edges raised by the displaced glass, as is shown in Fig 4, in which a deep scratch is intersected by a finer one. Smekal (1941) and his associate workers have made a thorough study of this phenomenon, and, using this ' one-grain method ' as a basis, have reached certain conclusions on the properties of glass as a typical brittle body.

Measurement of scratch hardness

All these phenomena within the micro-region are due to the plastic deformation of glass when the material is subjected to a pressure of the order of 500 kg/mm², as shown by the original studies of Bridgman and Simon (1953), in which a Vickers diamond was pressed into the glass until the area of the surface over which the pressure was applied corresponded to a pressure of 500 kg/mm². Scratching is done in a similar way.

Fig 4. Intersecting ' Sleeks ' on glass (2,400 × magnif).

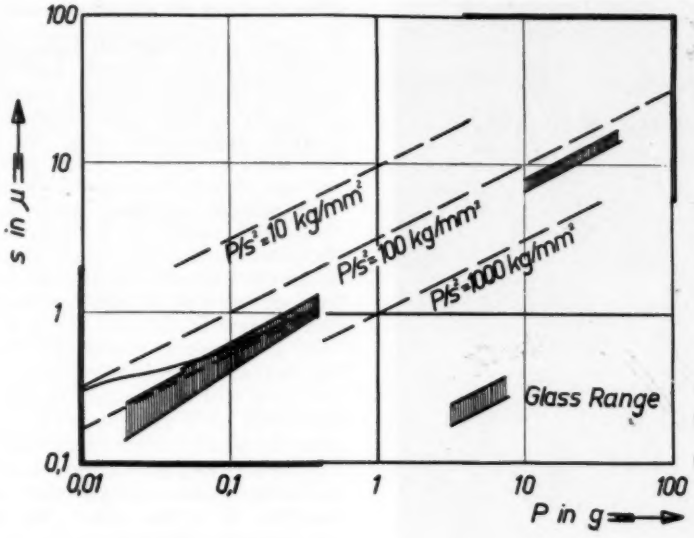

Fig 5. Range of hardness of glass as determined by scratching with a diamond under loads of 50 mg to 50 g. The breadth s of the scratch, in microns, is plotted against the load **P** *applied to the diamond in grammes.*

Measurements of this kind yield information on the hardness of glass. Scratch hardness measurements of the kind suggested by Mohs are particularly easy, though difficult to understand theoretically. Measurements can be made over a wide range of forces, varying from 50 mg to almost 50 g, and these will also suffice for orientation measurements. Fig 5 is a double logarithmic diagram showing the breadth of the tracks left by a diamond against the applied pressure *P*. The range of the ordinary glasses is shaded, and lies around 200 kg/mm². With forces above 50 g there is a risk of exceeding the permissible tensile stress of the glass, and so creating chatter flaws and the like (Ainsworth). Measurements in the course of which cracks have appeared should be treated with reserve, as should Vickers measurements which can produce doubtful crack systems at loads of only a few grammes (Fig 6). When the lower limit of the range of possible measurements is passed, the experimental difficulties increase, accuracy diminishes and elastic processes have to be reckoned with. Nevertheless, the scratch method has been used with success to prove that when a diamond is inserted at different depths into an old, lightly weathered glass, it first has to traverse a softer layer about 60 microns or 600 AU thick, before reaching the core material, which is about four times as hard (Schimmel, 1955). This result is of interest in regard to surface layers during polishing.

Plastic deformation plays an obvious role at the outset of the polishing process when pitch or felt pads are used with iron oxide and water. The peaks on the glass are furrowed through and sometimes carried over the edges of the depressions. Beilby (1903) thought that the glass was transported into the hollows, which were thus levelled off. However, this is not very likely, and it has never been observed. The products of abrasion are not often found in the hollows formed by the grinding either. The electron microscope has shown, at least in the case of felt polishing, that the grinding hollows are usually empty (Fig 7).

It may be different if the holes are practically ' polished out ' or if a hollow is broadened so as to spread out flat along the surface. In this case, parts of the bottom surface come within the range of working. The ' nests ' and extended hollows often show a distinct granular structure which seems to approximate to silicate masses

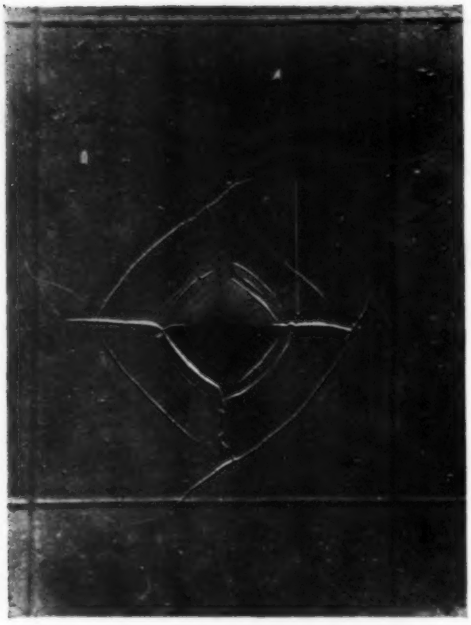

Fig 6. Impression made by a Vickers' diamond, with crack development around the impression (1,600 × magnif).

(Fig 8). In this end-stage of polishing the hollows are sometimes seen to have borders which may be ascribed to an ' influx ' of the surface layer. Similar appearances are found as flaws on completely polished surfaces (Fig 9). Often regions like this are surrounded by sharp edges or cracks. The areas between the cracks seem to lie rather lower, and to resemble almost polished-out hollows. They often contain accumulations of granular material.

The plastic deformation of glass and the consistency of the products of polishing are important for the removal of small irregularities, hollows, and cracks as polishing proceeds. The electron pictures show that irregularities can be smoothed away and cracks filled up. We can suppose that this process goes on continuously during polishing, in accordance with the observations of Preston. He found that the cracks due to chatter flaws could be made visible on a flat polished surface by etching the surface layer with hydrofluoric acid. If polishing is done with felt and iron oxide, but without water, the cracks become very distinct and it is difficult to arrest them.

The course of the polishing process

Level areas begin to form after polishing has gone on for a short time. Lord Rayleigh observed surfaces with an ordinary visual microscope and drew the correct conclusion that fully polished regions appear soon after the beginning of the polishing process. As the process goes on, the surface area of these polished regions is enlarged. The already polished areas with the grinding hollows between can be seen much more plainly from an electron microscope photograph (Fig 10), since the electron microscope gives greater depth of focus as well as high resolution. Even though only a few level areas are present at first, they will soon cover practically the whole surface. A decreasing number of hollows left behind by grinding will also occur on this surface. Beilby observed this process and deduced (wrongly) that the hollows were being filled in.

The electron microscope pictures show that as polishing goes on the flat surfaces increase rapidly. It is also quite clear that the working surface sinks during polishing so that the shallow hollows are removed first, and then the deep hollows. Obviously this means there is a progressive removal of the surface layer. In practice this process of removal takes up more than half

Fig 7. Partially polished ground surface of glass, showing empty grinding ' pits '. The black marks are calibration points (1,600 × magnif).

of the total polishing time. When enough of the top layer of glass has been removed to get rid of nearly all the grinding ' pits,' the last stage of polishing begins. This involves the removal of the layer that is damaged by the system of (filled-in) cracks. In practice this process seems to take up one-third or more of the total polishing time.

Removal of material and the Rayleigh-Beilby layer

As polishing goes on there is a continual removal of material from the surface of the glass. The fresh layer which is continually being formed cannot be observed as a rule. However, phenomena are sometimes seen in the electron microscope which give some indication of the existence of such layers. For example, under certain conditions these layers may build up on the surface of the glass, as shown in Fig 11.

As the uppermost layer of the glass is removed, the electron microscope becomes less capable of revealing the nature of the layer. In line with earlier writers, we may now ask whether the upper layer becomes plastic under the action of the polishing grains. We have discussed this

Fig 8. Glass surface in advanced stage of polishing, showing grinding ' pit ' almost completely polished out (8,000 × magnif).

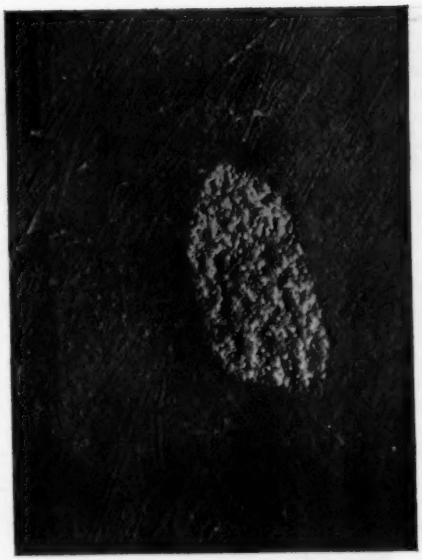

Fig 9. Defect on the surface of polished glass, indicating the removal of a layer which had built up on the surface (4,000 × magnif).

question elsewhere (1956), and found that several conditions have to be met. The polishing grains must be angular and the glass which is softened by their action must remain plastic for 10^{-4} seconds before it re-solidifies. If these conditions are present a plastic layer of glass could form on the surface. This layer, the existence of which is not proved, would form a covering. So far the electron microscope photographs have yielded no proof that the material is carried into the grinding holes, but indicate that the layer must be removed.

The mechanism of removal cannot be explained on the grounds of plasticity alone. Other processes must be involved. Preston (1930) postulated a reciprocal chemical reaction, and Hampton (1930) obtained confirmatory results from the chemical analysis of rouge cake. According to Preston, glass forms sodium silicate with water, and this eventually becomes colloidal silicate deposited in the polishing felt. According to Grebenchchikov (1946), a thin protective film is formed on glass in water, and during polishing this film is constantly broken down and carried away. Thus polishing gives rise to a continuous chemical attack and an associated progressive removal of material Kachalov (1946) supplied further experimental data. At the same time Klemm (1945, 1950) put forward the suggestion

Fig 10. Polished glass surface showing small grinding 'pits', which appear as peaks throwing shadows (360 × magnif).

that there was eutectic melting on the surface of the glass. More recently Kaller (1956) has further developed and discussed the chemical hypothesis on the basis of detailed determinations of the amount of glass removed. There can be no doubt that chemical processes play a very important part in the removal of the material. However, the question of how far these processes are due to the increase in temperature brought about by the action of polishing, and how far merely to mechanical friction, is still open. It must also remain uncertain whether the plasticity of the glass is of importance. Without mechanical rubbing it obviously will not be.

Thus the hypothesis of the 'Beilby layer' takes on a new aspect. It was assumed earlier that the mobile layer visible as a flat surface in the electron microscope was glass. Actually, this is very doubtful. If it is taken rather as a layer of silica gel or silicate compounds, as suggested by the German research workers, Jebsen-Marwedel, Lamesch and Loezer, many points become easier to understand. Beilby thought of the plastic surface layer named after him as composed of the same material as the underlying core, *ie* in our case, of glass. If we now decide that the surface layer is not the same as the core material, the question arises of whether this particular layer ought still to bear Beilby's name. Rayleigh's hypotheses were more general. He postulated the removal of a molecular or near-molecular layer. Perhaps, in tribute to both scientists, it should be called a Rayleigh-Beilby layer, as we have done recently (1956).

Some further observations

Defects in polishing are of practical importance since it is easier to get rid of them when their exact nature is known. There are too many types for us to deal here with those that are technically the most common, such as pitting, streaks, greyness, etc. Fig 9 shows a polishing defect or phenomenon which often appears just before the end of industrial plate glass polishing. Another polishing defect is shown in Fig 12.

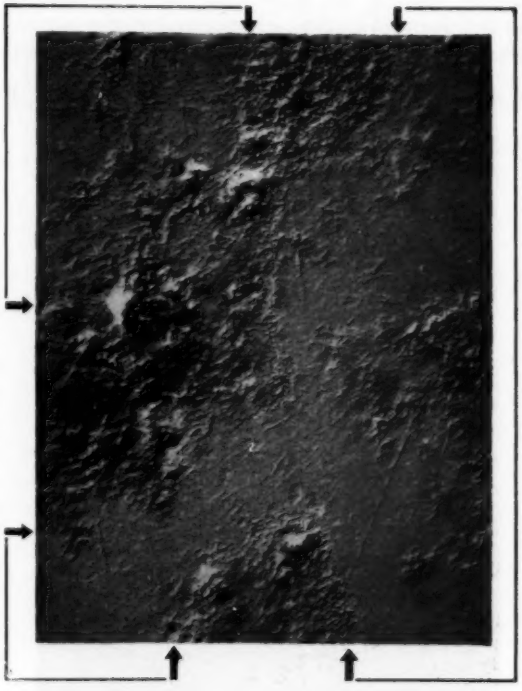

Fig 11. Surface during polishing, showing a well-defined area from which material which had built up on the surface had been removed; the limits of the area are marked by arrows (4,000 × magnif).

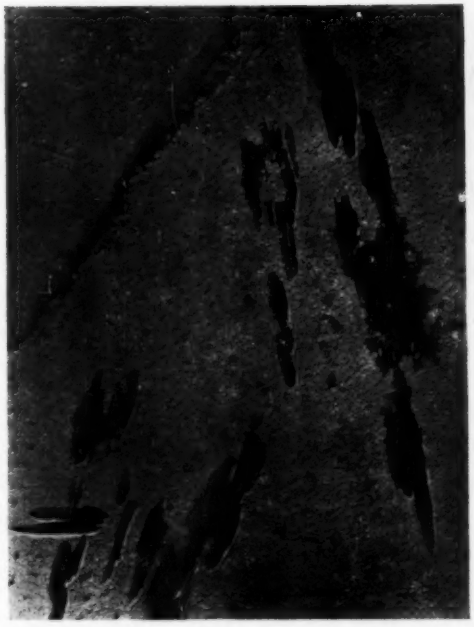

Fig 12. Defect on the surface of polished plate glass (2,400 × magnif).

Finally, let us take the case of a carefully cleaned glass surface and its alteration by weak chemical attack, such as is active during polishing according to the present hypothesis. Fig 13 shows the surface of a microscope slide glass which is several years old, *ie* which has been subjected for a considerable time to the action of the damp atmosphere. It has developed a soft surface layer. Numerous very small centres of attack show that the surface has been altered as well. The centres appear as circular regions about 100 millimicrons in diameter, *ie* about the same amount as was recently given (1955) for the thickness of the softened surface layer of the glass. The rate of attack is increased if dilute hydrofluoric acid is used (Fig 14). Apart from a certain roughness, larger circular areas of attack about 1 micron in diameter can be seen. There are also etching hollows usually elliptical, 10 microns and more in size. The etching pits are more interesting still. They are obviously the traces of former scratches, as observed by Preston, which have now been broadened so that they are plainly visible in the electron microscope.

Summarized account of the grinding and polishing process

In the grinding process, rotating abrasive grains act on the surface layer of the glass to produce fissures, cracks, and displacements. The surface layer is removed in this way and the layer below is loosened by a system of cracks (Preston).

The process of polishing is basically quite different. It involves the removal of any remaining peaks of the original surface, and removal of the loosened layer beneath (Fig 15a). In the first stage of polishing, the peaks are plastically deformed by the action of pressure (Smekal), though this is not the dominant process here. The main stage is the formation and enlargement of parts of the surface which have become smoothly polished and flat (Fig 15b); as these increase in area the peaks are progressively removed (Lord Rayleigh). When the bottom of the grinding holes has been reached, further polishing is needed to get rid of the layer containing the grinding cracks.

The removal of the glass takes place on the molecular scale (Lord Rayleigh, Brandt). Chemical reactions play an important part in this

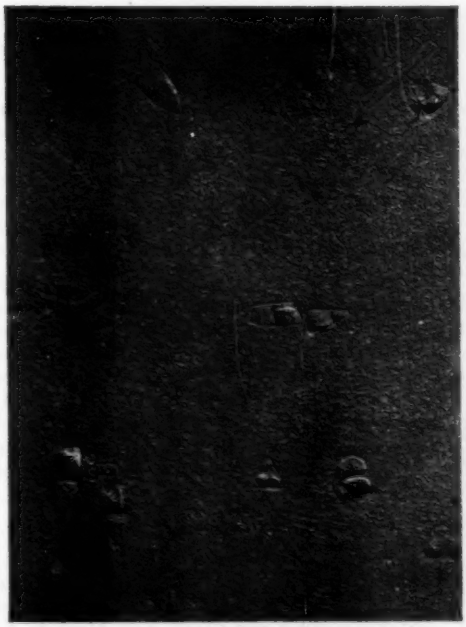

Fig 13. Glass surface after exposure to the atmosphere for several years (8,000 × magnif).

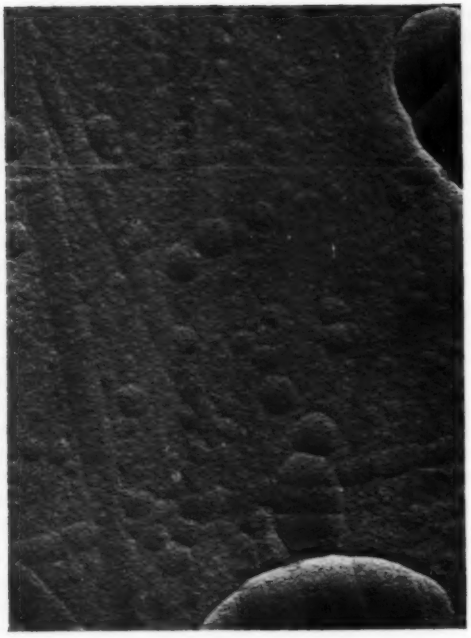

Fig 14. Glass surface etched with hydrofluoric acid (6,400 × magnif).

complicated process (Preston, Hampton, Bayer, Grebenchchikov, Kaller). So far the electron microscope studies have not proved capable of showing whether or not the detailed hypotheses, *eg* the formation of thin films which are torn away, are in accordance with the facts. Hydrolytic processes must be involved, and so must scratching.

The electron microscope shows that the surface layer is composed of a softer substance than the rest. This substance could fill up and eliminate shallow depressions. Deeper holes are not filled with this material as a rule. The hypothesis that the filling-in of the hollows is the predominant and progressive process in polishing (Beilby *vs* Reis and Markmann, Kaller) is not confirmed by our own work.

Acknowledgements

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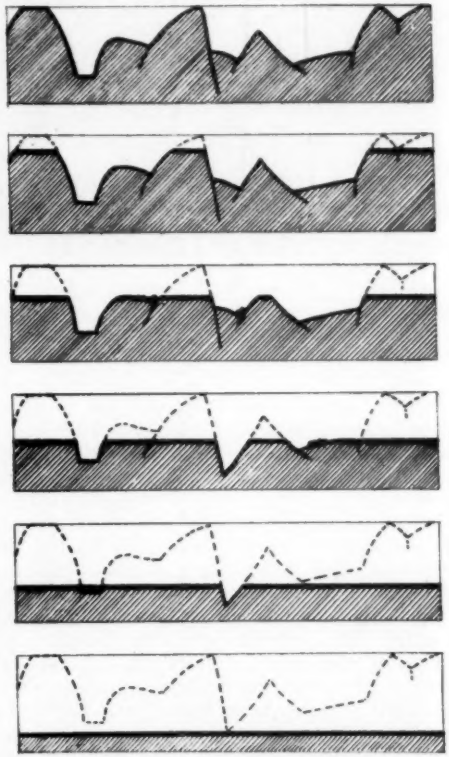

Fig 15. Diagram illustrating the progress of the polishing process: (a) ground glass showing grinding peaks; (b) partially polished surface with 'polished-on' layer; (c) accumulation of the products of polishing; (d) dislodgment of fragments loosened by extension and intersection of grinding cracks; (e) almost completely polished; (f) completely polished.

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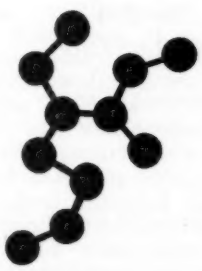

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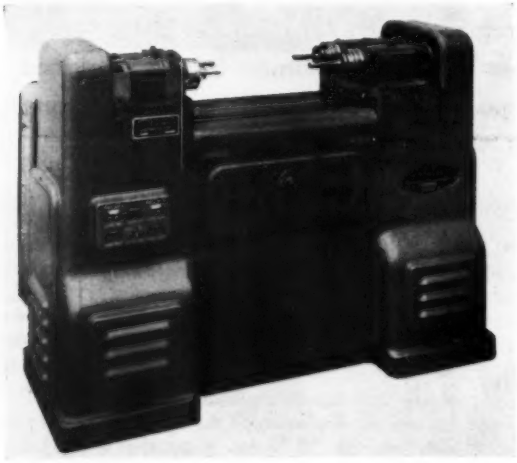

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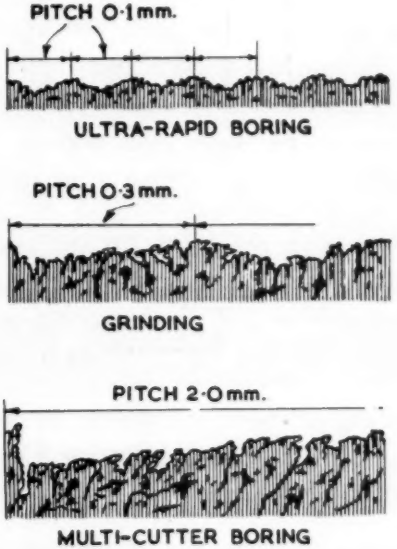

Fig 2. Diagram demonstrating the degree of roughness produced on cylinder castings by three methods of machining.

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